

WE CLAIM:

1. A method for the preparation of a cross-linked proton exchange membrane, comprising:
providing a sulfonated polymer;
dissolving the sulfonated polymer in a polar casting solvent;
adding at least one polyol cross-linking agent to obtain a solution, the at least one polyol cross-linking agent being added in a sufficient ratio of polyol molecules per repeat unit of the sulfonated polymer to generate cross-linking;
casting the solution to obtain the membrane; and
curing the membrane.
2. A method as claimed in claim 1, wherein the ratio of polyol molecules per repeat unit of the sulfonated polymer is above 1.
3. A method as claimed in one of claims 1 and 2, wherein the ratio of polyol molecules per repeat unit of the sulfonated polymer is between 2 and 3.
4. A method as claimed in any one of claims 1 to 3, wherein the sulfonated polymer is dissolved in the polar casting solvent to a concentration ranging between 5 and 25 wt%.
5. A method as claimed in any one of claims 1 to 4, comprising wherein the sulfonated polymer is dissolved in the polar casting solvent to a concentration ranging between 10 and 15 wt%.
6. A method as claimed in any one of claims 1 to 5, comprising agitating the solution prior to casting.

7. A method as claimed in any one of claims 1 to 6, comprising outgassing the cast solution.
8. A method as claimed in any one of claims 1 to 7, comprising drying the cast solution at room temperature.
9. A method as claimed in any one of claims 1 to 8, comprising curing the membrane under vacuum.
10. A method as claimed in any one of claims 1 to 9, wherein the membrane is cured at gradually increasing temperature.
11. A method as claimed in any one of claims 1 to 10, wherein the membrane is cured at a temperature ranging between 25 and 180° C.
12. A method as claimed in any one of claims 1 to 11, wherein the membrane is cured at a temperature ranging between 25 and 150° C.
13. A method as claimed in any one of claims 1 to 12, wherein the sulfonated polymer comprises a sulfonated poly(ether ether ketone).
14. A method as claimed in any one of claims 1 to 13, wherein the polar casting solvent is selected from the group consisting of DMAc, NMP, DMF, butyrolactone, water, a mixture of water and acetone, and a mixture of water and alcohol.
15. A method as claimed in any one of claims 1 to 13, wherein the polar casting solvent is selected from the group consisting of water, a mixture of water and acetone, and a mixture of water and alcohol.
16. A method as claimed in any one of claims 1 to 15, wherein the at least one polyol cross-linking agent comprises a diol.

17. A method as claimed in any one of claims 1 to 15, wherein the at least one polyol cross-linking agent is selected from the group consisting of ethylene glycol and glycerol.
18. A method as claimed in any one of claims 1 to 17, comprising sulfonating a polymer to a degree of sulfonation higher than 0.6.
19. A method as claimed in any one of claims 1 to 18, comprising sulfonating a polymer to a degree of sulfonation higher than 0.75.
20. A method as claimed in any one of claims 1 to 19, comprising drying the sulfonated polymer prior to adding the at least one cross-linking agent.
21. A fuel cell using a cross-linked proton exchange membrane prepared in accordance with any one of claims 1 to 20.
22. A proton exchange membrane suitable for fuel cells, comprising: a cross-linked sulfonated polymer provided from a solution which has been cast and cured, the solution including a sulfonated polymer dissolved in a polar casting solvent and at least one polyol cross-linking agent added to the dissolved sulfonated polymer in a ratio of the cross-linking agent molecules per repeat unit of the sulfonated polymer sufficient to generate cross-linking.
23. A proton exchange membrane as claimed in claim 22, wherein the ratio of polyol molecules per repeat unit of the sulfonated polymer in the solution is above 1.
24. A proton exchange membrane as claimed in one of claims 22 and 23, wherein the ratio of polyol molecules per repeat unit of the sulfonated polymer in the solution is between 2 and 3.

25. A proton exchange membrane as claimed in any one of claims 22 to 24, wherein the sulfonated polymer is dissolved in the polar casting solvent to a concentration ranging between 5 and 25 wt%.
26. A proton exchange membrane as claimed in any one of claims 22 to 25, wherein the sulfonated polymer is dissolved in the polar casting solvent to a concentration ranging between 10 and 15 wt%.
27. A proton exchange membrane as claimed in any one of claims 22 to 26, wherein the cast solution is outgassed.
28. A proton exchange membrane as claimed in any one of claims 22 to 27, wherein the cast solution is dried at room temperature.
29. A proton exchange membrane as claimed in any one of claims 22 to 28, wherein the solution is cured under vacuum.
30. A proton exchange membrane as claimed in any one of claims 22 to 29, wherein the curing of the solution is carried out at a temperature that is gradually increased.
31. A proton exchange membrane as claimed in any one of claims 22 to 30, wherein the curing temperature ranges between 25 and 180° C.
32. A proton exchange membrane as claimed in any one of claims 22 to 31, wherein the curing temperature ranges between 25 and 150° C.
33. A proton exchange membrane as claimed in any one of claims 22 to 32, wherein the sulfonated polymer comprises sulfonated poly(ether ether ketone).
34. A proton exchange membrane as claimed in any one of claims 22 to 33, wherein the polar casting solvent is selected from the group consisting

of DMAc, NMP, DMF, butyrolactone, water, a mixture of water and acetone, and a mixture of water and alcohol.

35. A proton exchange membrane as claimed in any one of claims 22 to 33, wherein the polar casting solvent is selected from the group consisting of water, a mixture of water and acetone, and a mixture of water and alcohol.
36. A proton exchange membrane as claimed in any one of claims 22 to 35, wherein the at least one polyol cross-linking agent comprises a diol.
37. A proton exchange membrane as claimed in any one of claims 22 to 35, wherein the cross-linking agent is selected from the group consisting of ethylene glycol and glycerol.
38. A proton exchange membrane as claimed in any one of claims 22 to 37, wherein the sulfonated polymer has a degree of sulfonation higher than 0.6.
39. A proton exchange membrane as claimed in any one of claims 22 to 38, wherein the sulfonated polymer has a degree of sulfonation higher than 0.75.
40. A proton exchange membrane as claimed in any one of claims 22 to 39, wherein the sulfonated polymer is dried prior to adding the at least one cross-linking agent.

AMENDED CLAIMS

received by the International Bureau on 28 July 2005 (28.07.05): original claims 1-40 have been replaced by amended claims 1-38 (5 pages).

WE CLAIM:

1. A method for the preparation of a cross-linked proton exchange membrane, comprising:

providing a sulfonated polymer having a degree of sulfonation higher than 0.5;

dissolving the sulfonated polymer in a polar casting solvent;

adding at least one polyol cross-linking agent to obtain a solution, the at least one polyol cross-linking agent being added in a ratio of polyol molecules per repeat unit of the sulfonated polymer higher than or equal to 1 to generate cross-linking;

casting the solution to obtain the membrane; and

curing the membrane.
2. A method as claimed in claim 1, wherein the ratio of polyol molecules per repeat unit of the sulfonated polymer is between 2 and 3.
3. A method as claimed in any one of claims 1 to 2, wherein the sulfonated polymer is dissolved in the polar casting solvent to a concentration ranging between 5 and 25 wt%.
4. A method as claimed in any one of claims 1 to 3, comprising wherein the sulfonated polymer is dissolved in the polar casting solvent to a concentration ranging between 10 and 15 wt%.
5. A method as claimed in any one of claims 1 to 4, comprising agitating the solution prior to casting.
6. A method as claimed in any one of claims 1 to 5, comprising outgassing the cast solution.

7. A method as claimed in any one of claims 1 to 6, comprising drying the cast solution at room temperature.
8. A method as claimed in any one of claims 1 to 7, comprising curing the membrane under vacuum.
9. A method as claimed in any one of claims 1 to 8, wherein the membrane is cured at gradually increasing temperature.
10. A method as claimed in any one of claims 1 to 9, wherein the membrane is cured at a temperature ranging between 25 and 180° C.
11. A method as claimed in any one of claims 1 to 10, wherein the membrane is cured at a temperature ranging between 25 and 150° C.
12. A method as claimed in any one of claims 1 to 11, wherein the sulfonated polymer comprises a sulfonated poly(ether ether ketone).
13. A method as claimed in any one of claims 1 to 12, wherein the polar casting solvent is selected from the group consisting of DMAc, NMP, DMF, butyrolactone, water, a mixture of water and acetone, and a mixture of water and alcohol.
14. A method as claimed in any one of claims 1 to 12, wherein the polar casting solvent is selected from the group consisting of water, a mixture of water and acetone, and a mixture of water and alcohol.
15. A method as claimed in any one of claims 1 to 14, wherein the at least one polyol cross-linking agent comprises a diol.
16. A method as claimed in any one of claims 1 to 14, wherein the at least one polyol cross-linking agent is selected from the group consisting of ethylene glycol and glycerol.

17. A method as claimed in any one of claims 1 to 16, wherein the degree of sulfonation of the sulfonated polymer is higher than 0.6.
18. A method as claimed in any one of claims 1 to 17, wherein the degree of sulfonation of the sulfonated polymer is higher than 0.75.
19. A method as claimed in any one of claims 1 to 18, comprising drying the sulfonated polymer prior to adding the at least one cross-linking agent.
20. A fuel cell using a cross-linked proton exchange membrane prepared in accordance with any one of claims 1 to 19.
21. A proton exchange membrane suitable for fuel cells, comprising : a cross-linked sulfonated polymer provided from a solution which has been cast and cured, the solution including a sulfonated polymer, having a degree of sulfonation higher than 0.5, dissolved in a polar casting solvent and at least one polyol cross-linking agent added to the dissolved sulfonated polymer in a ratio of the cross-linking agent molecules per repeat unit of the sulfonated polymer higher than or equal to 1 to generate cross-linking.
22. A proton exchange membrane as claimed in claim 21, wherein the ratio of polyol molecules per repeat unit of the sulfonated polymer in the solution is between 2 and 3.
23. A proton exchange membrane as claimed in any one of claims 21 to 22, wherein the sulfonated polymer is dissolved in the polar casting solvent to a concentration ranging between 5 and 25 wt%.
24. A proton exchange membrane as claimed in any one of claims 21 to 23, wherein the sulfonated polymer is dissolved in the polar casting solvent to a concentration ranging between 10 and 15 wt%.

25. A proton exchange membrane as claimed in any one of claims 21 to 24, wherein the cast solution is outgassed.
26. A proton exchange membrane as claimed in any one of claims 21 to 25, wherein the cast solution is dried at room temperature.
27. A proton exchange membrane as claimed in any one of claims 21 to 26, wherein the solution is cured under vacuum.
28. A proton exchange membrane as claimed in any one of claims 21 to 27, wherein the curing of the solution is carried out at a temperature that is gradually increased.
29. A proton exchange membrane as claimed in any one of claims 21 to 28, wherein the curing temperature ranges between 25 and 180° C.
30. A proton exchange membrane as claimed in any one of claims 21 to 29, wherein the curing temperature ranges between 25 and 150° C.
31. A proton exchange membrane as claimed in any one of claims 21 to 30, wherein the sulfonated polymer comprises sulfonated poly(ether ether ketone).
32. A proton exchange membrane as claimed in any one of claims 21 to 31, wherein the polar casting solvent is selected from the group consisting of DMAc, NMP, DMF, butyrolactone, water, a mixture of water and acetone, and a mixture of water and alcohol.
33. A proton exchange membrane as claimed in any one of claims 21 to 31, wherein the polar casting solvent is selected from the group consisting of water, a mixture of water and acetone, and a mixture of water and alcohol.
34. A proton exchange membrane as claimed in any one of claims 21 to 33, wherein the at least one polyol cross-linking agent comprises a diol.

35. A proton exchange membrane as claimed in any one of claims 21 to 33, wherein the cross-linking agent is selected from the group consisting of ethylene glycol and glycerol.
36. A proton exchange membrane as claimed in any one of claims 21 to 35, wherein the sulfonated polymer has a degree of sulfonation higher than 0.6.
37. A proton exchange membrane as claimed in any one of claims 21 to 36, wherein the sulfonated polymer has a degree of sulfonation higher than 0.75.
38. A proton exchange membrane as claimed in any one of claims 21 to 37, wherein the sulfonated polymer is dried prior to adding the at least one cross-linking agent.